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One of 12 ERTS-1 projects conducted by the University of Alaska
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16. Abstract
ERTS-1 imagery is providing a great deal of information regarding the manner in which Alaska is being tectonically deformed. Seismically active fault systems not previously recognized provide clues which assist in the interpretation of the manner in which the north Pacific lithospheric plate interacts with continental Alaska, producing earthquakes both in the area of interaction and in a large area of central Alaska surrounding it. There does not appear to be a simple Benioff zone in the area of subduction south of Mt. McKinley. Rather, a series of sub-parallel faults branching off of the Denali fault in a south-west direction appears to carry material of the oceanic plate around the inside of the great bend of the Alaska Range. North of the Alaska Range in the central interior, earthquakes appear to result from the grinding together of relatively rigid crustal blocks which are being driven by the forces arising in the subduction zone to the south. Earthquakes here are shallow, and have a marked tendency to occur at intersections of the faults and lineaments which outline the crustal blocks, and which are clearly visible on the ERTS-1 imagery.

17. Key Words (Selected by Author(s)) Fault, Earthquake, Seismicity, Alaska, Tectonics, Geology, ERTS	18. Distribution Statement		
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I: INTRODUCTION

This report sumarizes the work performed and conclusions reached during the second six months of contract no. NAS5-21833, ERTS-1 project 110-12, "Evaluation of feasibility of mapping seismically active faults in Alaska".

Receipt, logging, and dissemination of the data for this investigation, and for 11 other University of Alaska ERTS-1 projects is carried out under the auspices of ERTS-1 project 110-1. This project functions as the central coordinating facility for all University of Alaska ERTS-1 projects, and is receiving data to cover the entire state (while the test area of the present project probably does not include more than 1/10 the land area of Alaska).

To date, imagery of 165 scenes of central and south-central Alaska (the most populous part of the state, containing Anchorage and Fairbanks) have been received by the present project. Since many of the scenes are repetitive, probably not more than half the images have been inspected in great detail, with those showing the greatest contrast in topography receiving the greatest scrutiny. The parameter which influences detail the most (aside from cloud cover, of course) is sun angle, and those images produced during the winter (with sun angle of 10° or less) are of the greatest value to this investigation. The most significant findings to date have emerged from the finely detailed inspection of probably not more than 25 images, and these are referenced in the text where appropriate. Unless otherwise stated, it may be assumed that MSS band 7 has been found to be the most useful, although during some of the summer passes, band 5 is superior.

II: STATUS OF PROJECT

A. Objectives

It was the original purpose of this investigation to identify faults which were unmapped in the field, but which were suspected on the basis of ongoing seismicity. In this respect, the imagery has been spectacularly successful (as will be pointed out in the following sections), but a much broader application has been realized in the course of the investigation, and that is the utilization of ERTS-1 imagery as a tectonic mapping tool. Findings under the first objective would have provided some measure of seismic risk in populated areas (hence the choice of the study area). Those relating to the second can perform a much broader function in identifying stress systems which are responsible for tectonic deformation (with resulting earthquakes) on a regional scale. In particular, such information is helpful in explaining Alaska's role in global plate tectonics, particularly in the area where the north Pacific plate underthrusts the Alaska mainland along Cook Inlet and south-central Alaska.

B. Accomplishments During the Reporting Period

1. Recapitulation of findings during first semi-annual reporting period

In the interests of continuity, it would be well to briefly summarize some of the findings that were reported in the first semi-annual report, since much of the following discussion bears reference to them.

Oversimplifying, one might say that the findings previously reported fell broadly into one of the two categories which were outlined in the section on "Objectives". A good example of the first of these (i.e., the identification of previously unmapped seismically active faults) is the 120 km long fault (the site of a magnitude 4.8 earthquake in 1972) which extends from about 62°26'N, 149°23'W to 63°14'N, 147°44'W. It is gratifying that since this fault was first reported, it has been independently confirmed as being a major dislocation on the grounds of K-Ar dating of metamorphic rocks to either side of the fault (D. Turner, University of Alaska, personal communication). This feature is best seen in image ID no. 1066-20444.

The main emphasis in the previous report, however, was that information as to the regional stress system and the resulting tectonic deformation had been obtained by the discovery of a large-scale conjugate fault system in the Alaskan interior (note that this is not in conflict with the original purpose of the study, since one member of the conjugate fault system was the scene of a magnitude 6.5 earthquake in 1968, and is in close proximity to a major proposed construction project). It was reported that the system was composed of two intersecting sets of faults with a dihedral angle of about 55°, that they were situated around the outside of the great "bend" in the Alaska Range near Mt. McKinley, and that they appeared to be the result of outwardly directed compressive stress from around the bend. There will be further mention of this set of faults in the next section.

2. Summary of findings during the second semi-annual reporting period

We realize that, without appropriate illustrations, verbal descriptions of many of the reported findings are about as enlightening to the reader as giving directions by flailing one's arms in the dark. While the final report on this project will contain the needed figures, they are, unfortunately, not available at present.

The following sub-headings categorize the features which have received the greatest scrutiny during the past reporting period.

a. Central Alaska conjugate fault system

The conjugate fault system described in the previous semi-annual report and in an interim scientific report (Gedney and VanWormer, 1973) has been found, on imagery from some of the spring passes (image ID nos. 1216-21192 and 1251-21135) to be of even greater extent than previously reported. Members of the set are seen in the western Ray Mountains north of Tanana, and in the Kokrine Hills north of the Yukon River at about 154°W longitude. Two earthquakes of magnitude 6-1/2 to 6-3/4 occurred at approximately these locations in 1958 (Davis and Echols, 1962) and may have been associated with these faults. Epicentral locations at that time were very rough, however. Further, it appears from some of the images in the northern part of the study area (c.g., image ID 1216-21190) that members of the set may even extend as far north as the southern Brooks Range (!).

b. Crustal structure in the central interior

The tectonic regimes separated by the line of the Alaska Range are vastly different in character. South of the Alaska Range, along Cook Inlet and the Susitna River lowlands, earthquakes are of intermediate depth, and the focal volume outlines a well defined Benioff zone along which the north Pacific plate is being underthrust beneath the mainland (Davies, 1973). Northward from here, in the central interior, all earthquakes are of shallow origin, and appear to be the result of coupling with the north Pacific plate around the "corner" of the range at Mt. McKinley.

From ERTS-1 imagery, it appears that the central interior north of the Alaska Range is composed of a "block"-like structure, with earthquakes occurring along the boundaries of the blocks and at intersections where three or more blocks come into contact. These findings were reported in the fourth bi-monthly progress report (March 31, 1973) and in an interim scientific report dated May 25, 1973. The significant point is that the major earthquakes in the area tend to occur at the intersections of the lineaments outlining the various blocks, and that these intersections are clearly visible on ERTS imagery.

As reported, these lineaments may either be old faults, dating back to the Cretaceous, they may be unmapped faults of the same equivalent age which are supplemental to the mapped set, or they may be members of the conjugate fault system discussed in the previous section. A seismicity model is thus envisaged where relatively thin crustal blocks are being ground together under a driving mechanism related to underthrusting of the north Pacific plate.

c. Crustal structure in south-central Alaska

South-central Alaska is presently the only known place in the world where a major subduction zone for a lithospheric plate lies in mid-continent. The dipping focal zone extending up Cook Inlet and the Susitna River lowlands to Mt. McKinley marks the surface along which the floor of the north Pacific is being underthrust beneath the western Alaska Range, and the great bend in the range near Mt. McKinley appears to mark a "corner" of the underthrust plate. The interactions here are understandably complex.

ERTS-1 imagery is providing new insight into the manner in which tectonic deformation is happening in this corner.

It is conceptually difficult to envisage the manner in which the Pacific plate disappears beneath the mainland here. Does it simply "tear away" along the line of the Denali fault (which trends generally east-west along the midline of the northern Alaska Range), or are other factors involved? First of all, the Denali fault is traditionally mapped as exiting from the Alaska Range west of Mt. McKinley and extending into the lowlands of south-western Alaska (Dutro and Payne, 1957; King, 1969). On some recent ERTS-1 imagery, (ID no. 1266-20572) it instead appears possible that the main part of the fault does not follow this course, but continues bending with the range to the vicinity of Rainy Pass (about 62°N). This unmapped "strand" of the Denali apparently splits off from the mapped part at about 62.9°N, 151.8°W. This same image also shows an unmapped, roughly parallel branch about 100 km to the east, extending from about 63.2°N, 149.5°W to 62.0°N, 151.2°W. Significantly, this also parallels still another branch (or strand) of the Denali fault about 80 km further yet to the east. The latter fault is the one which was previously identified and reported to be an unmapped, seismically active fault, and which was subsequently found to be a major discontinuity on the grounds of K-Ar dating. Henceforth, we refer to this feature as the Susitna fault.

The possibility which arises from these findings is that the north Pacific plate, rather than merely tearing away from the surface along the Denali fault and being underthrust along the eastern flank of the (western portion of the) Alaska Range, is also being forced "around the corner" of the inside of the great bend. In other words, the set of sub-parallel faults leading off to the south-west from the mapped portion of the Denali fault may be performing in the manner of a deck of cards which is being deformed by sliding the top and bottom cards in opposite directions. The evidence (from fault-plane solutions) that right-lateral motion occurred on the previously reported fault occurred during an earthquake in 1972 supports this notion.

d. Miscellaneous findings

Minor lineaments and structures which have been "picked"from the ERTS-1 images are too numerous to relate here. They will, however, appear on the final versions of maps and overlays that result from this investigation.

For the present, one further observation will be made regrding the structure of the central interior. Among Alaska's principal tectonic features are a number of great transverse faults which traverse the state roughly from east to west. The Denali is one of these. Another is the Kaltag fault extending westward from the vicinity of Tanana. King (1969) shows this fault south of the Yukon River and west of Tanana to be single-branched and "buried". On the imagery (ID nos. 1216-21192 and 1251-21135) it would appear that the Kaltag is a double feature here with the two branches being separated by about 25 km. The most striking thing about this feature is the "herringbone" drainage pattern achieved by apparently offset streams in the block between the two branches. The relative offset of the streams to either side of the block (if they have actually been offset) would be about 15 km. Admittedly, some other agent may have been responsible for this fascinating pattern (such as sand dunes formed subsequently to the last glacial period). Ground truth is lacking in this area.

e. Cooperative studies

We have striven, throughout the course of this study, to develop a free and unemcumbered exchange of ideas with others who have an interest in ERTS and in the tectonics of Alaska. After the appropriate clearance from NASA, we have presented papers dealing with ERTS-1 derived data on three occasions during the past reporting period, and at least one will be presented during the next period. These presentations were made at the ERTS-1 symposium on significant results in March, to the Alaska tectonics discussion group at the University of Alaska in March, and to the annual meeting of the Seismological Society of America at Golden, Colorado in May. During August, a further paper will be given before the joint U.S.-Japan conference on earthquake prediction and control to be held in Boulder, Colorado.

III: NEW TECHNOLOGY

None

IV: PLANS FOR NEXT REPORTING PERIOD

Acceptable data for most of the study area have now been received, although little is available of the Chugach Mountains because of an apparently perennial cloud cover. Although the coverage is nearly complete, we are not submitting a revised standing order form because we wish to obtain a complete seasonal set under all possible climatic conditions and sun angles.

The recently-arrived VP-8 image analyzer is now in operation under the supervision of University of Alaska project 110-1 and, although the investigators of the present project have not yet had any experience in using this instrument, we hope to be able to find applications to this investigation in the months to come.

Seasonal comparisons are now being made and will continue, although it is becoming more apparent that the winter passes at low sun angle will continue to be the ones upon which we will rely the most heavily. The time has now come for us to begin to consolidate our findings and to arrange them into some easily presentable and digestable format. Therefore, it appears that much of the remaining time under this contract will be spent in the preparation of figures and diagrams for publication and for the final report. A final round of discussions with persons from the various geological disciplines at the University of Alaska will be held in order to present as broad an interpretation as possible.

V. CONCLUSIONS

Central Alaska and south-central Alaska are two adjacent areas which are extremely seismically active, but which owe their seismicity to two radically different forms of deformation although they probably share a common driving mechanism. That mechanism is the stress system induced by the north-westward migration of the north Pacific lithospheric plate.

South of about 63°N, the plate is being underthrust along the eastern flanks of the Aleutian Range and the Alaska Range. Here, earthquakes occur in a dipping focal zone along which relative motion between oceanic and continental plates is occurring. Intermediate focal depths are the rule. It also appears that material is being squeezed around the inside of the great bend of the Alaska Range, and that much of this motion is being taken up along a series of sub-parallel faults which are seen on ERTS-1 imagery to extend as strands off the Denali fault. These strands are all seismically active.

North of the Alaska Range, in the central interior, all earthquakes are of shallow origin, and appear to be the result of a fragmented crust being "ground" together along the margins of abutting crustal blocks. The driving mechanism is most likely the transmittal of stresses from around the great bend in the Alaska Range arising from migration of the north Pacific plate. It is significant that the larger earthquakes in the interior tend to occur at intersections where three or more blocks come into contact, and it can probably be expected that the same behavior will continue in the future. ERTS-1 imagery provides a natural method by which to outline these crustal blocks and the intersections of faults and lineaments which define them.

VI: RECOMMENDATIONS

We would urge that the practice of using the small waxed-paper envelopes to protect the 70mm film chips be re-instated. The new transparent plastic envelopes are impossible to stamp or write on except with a grease pencil, they are difficult to open, disinclined to stack neatly or without sliding around, and they absolutely refuse to be catalogued in a standard computer-card file.

VII: PUBLICATIONS

a) In preparation:

Gedney, Larry and James VanWormer, Earthquake probabilities in selected areas of Alaska based on b-slope monitoring, To be presented to the U.S.-Japan Conference on Earthquake Prediction and Control, August 13-15, 1973, Boulder, Colorado (Copies of abstract have been supplied to NASA).

VII: PUBLICATIONS (continued)

b) In press:

Gedney, Larry and James VanWormer, Some aspects of regional tectonics in Alaska as seen in ERTS-1 imagery, ERTS-1 Symposium Proceedings, March, 1973.

Gedney, Larry and James VanWormer, Tectonic mapping in Alaska with ERTS-1 imagery, Photo Interpretation.

c) Published:

Gedney, Larry, "Finding faults" with ERTS-1 imagery, The Northern Engineer, Vol. 5, No. 1, pp. 3-5, Spring, 1973.

VanWormer, D., L. Gedney, J. Davies, and L. Shapiro, Central Alaska seismicity, 1972, Program with Abstracts, 68th Annual National Meeting of the Seismological Society of America, p. 49, 19 May, 1973.

Gedney, Larry and James VanWormer, Some aspects of regional tectonics in Alaska as seen in ERTS-1 imagery, Symposium on Significant Results obtained from ERTS-1, Abstracts, Paper G-23, March, 1973.

Gedney, Larry and James VanWormer, Tectonic mapping in Alaska with ERTS-1 imagery, interim scientific report, NASA Contract NAS5-21833, 25 May, 1973.

VanWormer, D., J. Davies, and L. Gedney, Central Alaska earthquakes during 1972, Scientific Report UAG R-224, Geophysical Institute, University of Alaska, August, 1973.

Note: Reference to some of our work has been made in two scientific periodicals (Science, 13 April 1973, p. 173; Geotimes, May, 1973, p. 19) and permission has been given to Dr. Nelson R. Nunnally of the University of Oklahoma to present some of our results in a forthcoming article.

VIII: REFERENCES

Davies, J. and E. Berg, Crustal morphology and plate tectonics in south central Alaska, Bull. Seism. Soc. Am., 63, 673-677, 1973.

Davis, T. N. and C. Echols, A table of Alaskan earthquakes, 1788-1961, Geophysical Institute, University of Alaska Research Report No. 8, UAG-R131, 1962.

Dutro, J. and T. Payne, Geologic Map of Alaska, U. S. Geol. Survey, 1957.

Gedney, L. and J. VanWormer, Tectonic mapping in Alaska with ERTS-1 imagery, interim scientific report, NASA Contract NAS5-21833, March, 1973.

King, P., Tectonic map of North America, U. S. Geol. Survey, 1969.

APPENDIX A: CHANGE IN STANDING ORDER FORM

None.

APPENDIX B: ERTS DATA REQUEST FORMS

None.

APPENDIX C

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY

D

N

ID

DATE 1 August 1973

PRINCIPAL INVESTIGATOR Larry Gedney

GSFC UN601

ORGANIZATION Geophysical Institute, University of Alaska

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Fault	Mountain	River	DESCRIPTORS
121621192M	x	x	x	
121621190M	x	x	x	bed
122620340M	x	x	x	
122720392M	x	x	x	
122720394M	x	x	x	
125021083M	x	x	x	
125121135M	x	x	x	
126220340M	x	x	x	
126620572M	x	x	x	glacier

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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APPENDIX D: SIGNIFICANT RESULTS

PRINCIPAL INVESTIGATOR: Larry Gedney

TITLE OF INVESTIGATION: Evaluation of feasibility of mapping seismically active faults in Alaska.

DISCIPLINE: Mineral Resources, Geological Structure and Landform Surveys.

SUBDISCIPLINE: Earthquake zones investigations.

SUMMARY OF SIGNIFICANT RESULTS:

The sharp bend in the Alaska Range near 65°N, 150°W (near Mt. McKinley) is now thought to enclose a corner of the northwesterly migrating north Pacific lithospheric plate. Subduction of the plate beneath the continent is believed, on the basis of hypocentral distribution, to occur along Cook Inlet and the eastern flanks of the Aleutian and Alaska Ranges as far northward as Mt. McKinley.

The nature of tectonic deformation here, particularly in the area of the bend in the Alaska Range, is understandably complex. The Denali fault, trending generally east-west through the northern part of the Alaska Range, is thought to be of a transform character in the vicinity of Mt. McKinley (i.e., it is thought to be the "surface" along which the oceanic plate separates from the continental plate). On the ERTS imagery, however, it appears that there are a number of sub-parallel faults which branch off of the Denali fault in a south-westerly direction. Slippage along these would tend to "squeeze" material around the inside of the bend rather than the plate being directly underthrust. All of these sub-parallel faults are seismically active. The three which are most noticeable on the imagery have end points at approximately 62.9°N, 151.8°W and 62.1°N, 153.6°W; 63.2°N, 149.5°W, and 62.0°N, 151.2°W; 62.4°N, 149.3°W and 63.2°N, 147.7°W. The latter fault is one which produced a magnitude 4.8 earthquake in 1972. The right-lateral fault-plane solution obtained for this event is consistent with the concept of slippage "around the bend" on a set of sub-parallel faults in the manner postulated.

The best images to show these features are image ID nos. 1066-20444 and 1266-20572.